THE ANALYSIS OF THE ACTION OF THE VAGUS NERVE UPON THE HEART.

PRELIMINARY NOTICE.

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In a former investigation, carried on in 1895–96 in the laboratory of Prof. Th. W. Engelmann in Utrecht, I was enabled to demonstrate that there exist reflexes from the point of the ventricle upon the centrifugal nerves of the different parts of the heart, the reflex centres being in the medulla oblongata.* These reflexes were for the most part standstills, similar to those produced by striking the intestine of the frog (Reflex of Goltz). In studying these reflexes I found that, during the so called standstills, frequently only the ventricle stops, the auricle meanwhile, or still more frequently a certain part of the sinus, continuing to beat, with perhaps a slight retardation, sometimes even with increased frequency. My research work with Dutch frogs convinced me that this phenomenon must be ascribed to a decreased conducting power. By the influence of the Vagus nerve the passage of the contraction wave over the heart muscle can be blocked. It became clear that the conduction of the peristaltic contraction is a function of the heart, which up to the present time has been too little regarded, especially in the German and French literature on the subject. As to the literature in the English language, there is the admirable work of Gaskell upon the action of the Vagus in the tortoise,† and those of McWilliams, and of Bayliss and Starling, on the innervation of the mammalian heart. Moreover, the conducting power of the heart has received attention from Engelmann, Wesley Mills, G. N. Stewart, Knoll, Reid Hunt, and Harrington. The surprising fact that, in a sub-

* Royal Dutch Academy of Sciences, Session of Oct. 26, 1896, and Pflüger's Archiv., Band LXVII. p. 135.

† Journal of Physiology, Vol. IV. p. 43.

ject so thoroughly studied as the physiology of the Vagus, this most important function has received such slight attention and is so imperfectly understood, may be due to the not less surprising circumstance, that students of the physiology of the heart have in a peculiar manner overlooked the more central parts of the organ, the very source of the heart revolutions, viz. the large veins. Especially is this the case with regard to the influence of nerves upon the heart. Most investigators have contented themselves with observing simply the ventricle. Gaskell and Engelmann and Bayliss and Starling recorded systematically the movements of the ventricle and the auricle: no one thus far has studied the influence of nerves of cold-blooded animals upon ventricle, auricle, and sinus, recording the movements of all these parts at the same time. Knoll very recently did so with great skill in the mammalian heart; the conditions are there, however, much less favorable for an analysis of the Vagus action, as it has been found by me to exist in the case of the amphibian heart. By simply recording the movements of the sinus alone under Vagus action, this part of the heart proves to be capable of quite complicated forms of activity. The Vagus is able to dissociate the movements of the large veins in a manner well adapted to throw light upon the cause of the normal heart-beat. While the auricles and ventricles undoubtedly perform the most important functions in the mechanical work of maintaining the circulation, we have to look upon these portions of the heart, as far as their rhythmical motions are concerned, as under the control of influences proceeding from the large veins. In regard to this point, the study by Engelmann of the muscular properties of the sinus, published in 1896,* and Tigerstedt and Stromberg's previous work on the same subject, are to be consulted.

A second important point in which my experimental work differs from that of my predecessors is, that I forsook the customary method of excising the heart with the adherent Vagus nerves. In both series of experiments, in Holland as well as in America, I have been able to show that the functions of the heart, and still more the normal action of the Vagus, are injuriously affected by the least lack of normal nutrition. I have, therefore, taken the greatest care, in employing the suspension method of Engelmann, to attach the different parts of the heart to the recording levers in such a way that the circulation through the heart and the body was interfered with as little as possible. The slightest loss of blood is constantly followed by changes in the force, and still more by changes in the conducting power

* Pflüger's Archiv., Band LXV. p. 109.

of different parts of the heart. It is easy to prove that the diminished force of the ventricular contractions in Vagus stimulation as studied by Heidenhain and Gaskell can be observed only in cases of imperfect nutrition caused, for instance, by loss of blood. There is no reason to believe that the Vagus nerve has any influence upon the force of the normally nourished ventricle or upon that of the normally nourished veins, although a negative influence of Vagus stimulation upon the force of the auricle seems to be a constant effect. The phenomena described by Heidenhain and Gaskell may perhaps belong in the same category as the "staircase" of Bowditch; at all events, I could in the American bull-frog (R. Catesbeiana) easily demonstrate, as an effect of stimulation after bleeding, a rapid decrease or disappearance of the ventricular contractions, which simulates a standstill. After this standstill the contractions came gradually back to their former force. The same staircase-like phenomenon can, after somewhat more prolonged anæmia, be observed also in the auricle, not, however, in the large veins.

A third point in my experiments which may be worthy of mention is the manner in which I stimulated the Vagus. I needed to find a method which can be used without any operation or loss of blood. Moreover, it was desirable to stimulate both Vagi, as one often finds them not equally effective. For this purpose a special instrument was constructed, which is to be fixed in the Tubæ Eustachii, and which will hereafter be fully described. Of the details I will mention here merely that twenty-four hours before the experiment the animal received a small dose of curare, which was insufficient to cause complete paralysis. It may also be mentioned, that I have made a special study of the analysis of physiological standstills, which last from some seconds to half a minute. In frogs, with good reflex irritability, treated as above described, one very often sees, without any stimulation, spontaneous standstills. These normal standstills never last so long as, for instance, those observed by Gaskell with prolonged faradization. I have avoided these standstills, in the conviction that in that way new factors are introduced, viz. insufficient nutrition during and after a standstill.

The analysis of the dromotropic * and of the chronotropic † effect of the Vagus upon the different parts of the heart is attended with the greatest difficulties. The further the analysis proceeds the more it becomes obvious that phenomena apparently belonging to the chronotropic effect can

* Influencing the conducting power.

† Influencing the frequency of the contractions.

be referred to dromotropic influence. With more refined methods of recording cardiac phenomena, it is extremely probable that the importance of the dromotropic as compared with the chronotropic influence will be found to be still greater than it can now be shown to be. The stimulation of the dromotropic fibres of the Vagus causes dissociation in the activity of the different cavities of the heart, affecting the conduction of the contraction wave, not only between auricle and ventricle and between sinus and auricle, but even between the component parts of the sinus itself. The effects upon the conduction between sinus and auricle and between auricle and ventricle are very often in an opposite sense.

The interference of accelerator and retarding nerves upon the heart, investigated by Bowditch, Ludwig, Baxt, and Hunt, may find its interpretation in the dromotropic action of the Vagus.

In this preliminary notice it seems impracticable to give more details; the results, with the discussions to which they lead, will be published in full in the "American Journal of Physiology."

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